From: William Pellico, PIP Leader

Bob Zwaska: PIP Deputy Leader, Fernanda G. Garcia: PIP Linac Manager, Keith Gollwitzer: PIP Booster Manager, Kenneth Domann: PIP Planning Controls

Subject: Proton Improvement Plan

Project Quarterly Summary FY15 Q1

Report #9 Feb 2, 2015

Project Milestones

There were 4 scheduled milestones this quarter for PIP. Three milestones were Linac level 3 and one level three for Booster. All milestones were completed.
Linac WBS Linac Laser Notcher: *Beam shaping technology chosen*. This milestone was complete.
Linac WBS Utilities / LCW/Dual Temp system: *Complete Installation of new dual temp system*
Linac WBS Utilities / LCW/CUB 55 LCW spare pump: *Complete55 LCW spare system.* Both these milestones were complete and with that, mark the completion of two more Level-4 WBS.
Linac WBS Utilities/LCW: *Linac LCW system complete.* This marks the completion of all utilities Level-3 WBS milestones within PIP Linac. Table 1 below gives some additional milestone details for FY15 Q1.
The lone booster milestone was for the completion of the new Booster anode supply specification and documentation.

PIP Highlights by WBS Section

WBS 1.1 Linac

The vulnerabilities associated with the LINAC are the 200 MHz accelerating system, including power amplifier tubes and other associated systems such as the modulator; utilities for power distribution and vacuum systems; better need for reliable instrumentation along the Linac to improve beam transport and realistic machine model supported by real beam measurements. There are four largest elements of WBS Level 2 in Linac which are further subdivided at Level 3.

WBS 1.1.1 200 MHz RF Power System

The 200MHz RF Power System represents a significant part of the total scope of the PIP project. There are 3 level 4 elements which will be described below.

WBS 1.1.1.1 High Level RF

The klystron prototype is moving along pretty well. Work is focused on the drafting of the klystron. Most of the effort is on detailing the solenoid and frame of the klystron along with the required external x-ray shielding. In parallel the designs of the gun isolation tank and collector cooling and lead shielding are being finalized. The L2 manager (Fernanda G. Garcia) visited CPI in November to meet the design team and discuss any open action items. The orientation of the coax was finalized as being vertical, the input RF driver was reported to have a Type-N output, the interface connection panel location was specified, and the requirements for the filament transformer were accepted. The seal-in assembly drawing was completed previously and all of the parts are on order. Many parts are due in to CPI in mid-January. The long lead items such as the cathode, collector, window, and drift tubes are due in late-January.

As mentioned above, during this quarter the L2 manager met with CPI team and also arranged a face-to-face meeting with SLAC team to further discuss the possibility of performing the final acceptance test at SLAC, utilizing their P2-Marx modulator. The one day meeting was carried on and it was very productive. Fernanda was able to visit the area where the P2-Marx modulator is located and where the proposed klystron test would take place. Following the tour at the facility, a meeting was held between Fernanda and SLAC team to discuss item by item what the test would involve and how Fermilab/SLAC would organize the test. As part of the discussion it was raised again the possibility to revise one more time the limitations on the company test stand capability. As part of the action post meeting, Craig Burkhart consulted CPI senior engineer and received a verbal agreement that CPI would actually be able to fulfill at full extend the acceptance tests at their facility. This is good news as it significant reduces cost to prepare the area at SLAC, ship the tube, re-assemble the system and execute the test procedure and finally repack the klystron and ship once again to Fermilab. According to the lead engineer, the limitations discussed early on were related with the former incarnation of the tube at higher power. L2 manager conferred to Fermilab procurement office and there is no impediment as far the contract goes in proceeding with this approach. At the end of the quarter, an email was sent to SLAC asking for a written confirmation from CPI that indeed the full acceptance test can be performed at the company site with Fermilab team and SLAC team participating of the whole process.

WBS 1.1.1.2 Linac Modulator

AD/EE Support Design: Work is progressing well on developing a prototype modulator capable of replacing the present tube based design. During this quarter an assembly fixture was developed and manufacture which will be used to build the cells. The purpose is to keep each cell having identical dimensions, which will enable the user to swap cell without making any fine tuning adjustment, speeding up the process of cell recovery. One cell has been built so far, with the goal of completing the 9 cell, each with low inductance strip line, for testing in the lab with the current shunting board. Once tested, these cells will be mounted in the cabinet, along with 16 other cells for the 25 cell testing. The short circuit testing has some problem distinguishing between the normal turn on current of the IGBT and the short circuit current. A filter was added to the circuit ant it appeared to solve the problem, but was not the ideal way to fix the problem. A new approach was developed that would replace the B-Dot board, which used voltage instead of picking up current, to shunt the output of the cell during short circuit. This approach would work better since it will not be sensitive to stray magnetic fields. However, before pursuing any further, another change was added to the B-Dot coil. The outcome of the tests was successful, so the team decided to proceed with the B-dot choice.

In total there will be 7 control boards for this project. During this quarter 5 out of the 7 was complete. Also progress on the controls topology was performed this quarter, with the ultimate goal of finalizing the overall design to the last two circuit boards.

WBS 1.1.1.3 7835 Procurement

The final of the planned triode power tubes under PIP were procured and delivered to Fermilab during FY15 Q1. Therefore, Linac has presently an in-house inventory of 4 years. This marks the completion of this Level-4 WBS within PIP.

WBS 1.1.2 Accelerator Physics

WBS 1.1.2.1 Simulations and Studies

In the last report it was said that the team planned to release the draft final paper late this quarter. This was not achieved mostly due to manpower reassignment to other activities. This task has been declared complete as far PIP WBS tracking is concern.

WBS 1.1.2.2 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.2.3 Linac Notch Creation

The main accomplishment during this quarter was to perform an experiment to demonstrate partial neutralization of the linac beam. This request was motivated after a successful Accelerator Advisory Committee (AAC review) late fall. For that, the monitoring laser used to monitor the mirrors reflectivity at long term, is too weak to perform the neutralization. The team identified another laser available on site which has enough pulse length and power capability (10 nsec / 100 mJ) to neutralize the beam. The optical setup initiated early December which the team worked with ES&H division to obtain the appropriate training and permission to use the laser at a public area. The initial characterization and setup of the optics was developed at the laser laboratory. The laser system setup, together with the optical box, was moved from the lab area to the injector line middle December. All the necessary triggers, timing and monitoring devices were identified and setup over the holiday period. Upon receipt of approval to operate by ES&H officer, the tests were performed off-hours when the foot traffic at the gallery was minimal. Figure 1-3 below show the optical setup in place at the injection area, the creation of the beam notch and the laser profile used to create the notch respectively.

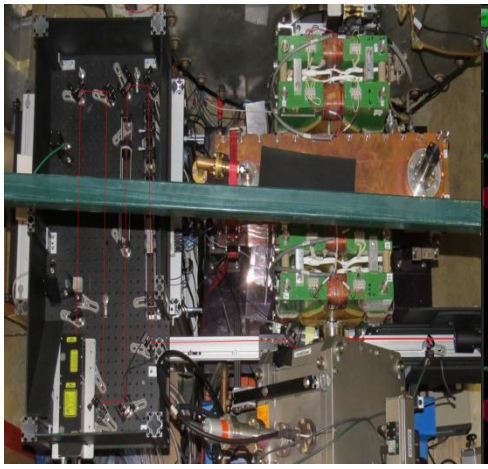


Figure 1: Laser optical box installed at the exit of the RFQ.

Figure 2: Notch neutralization demonstration

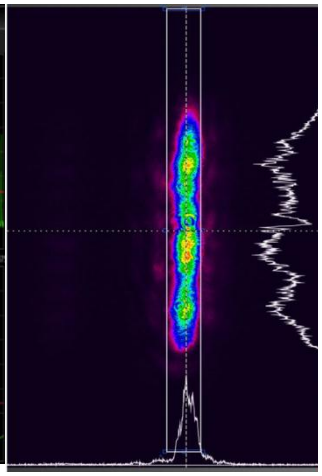
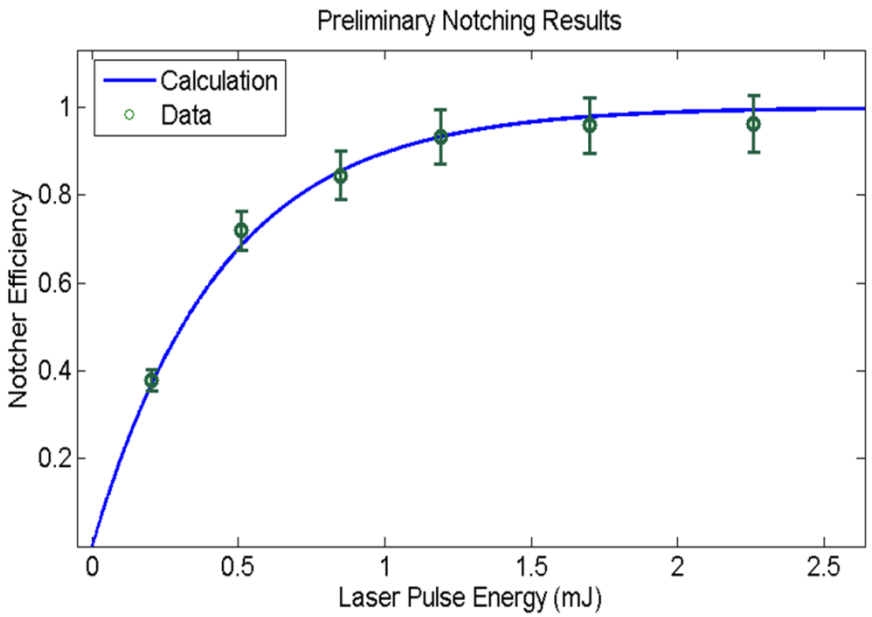


Figure 3: Laser temporal profile

The preliminary laser notching efficiency was extracted from the measurements (figure 4). The specification for the laser notch being built by PIP team is 2mJ to obtain approximately 99% neutralization. The test confirms the theoretical prediction. This is a tremendous success for the design team to be able to demonstrate the ability to create the notch at 750 keV.

Figure 4 Laser Notcher efficiency scan



WBS 1.1.3 Instrumentation

WBS 1.1.3.1 Beam Position Monitors

First Linac Level-3 WBS completed (FY13-Q2).

WBS 1.1.4 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.5 Utilities

The Linac Utilities, such as power distribution, water and vacuum systems are composed of mostly 40 year-old equipment beyond its practical service life. There are three Level 4 elements in this WBS.

WBS 1.1.5.1 Power Distribution

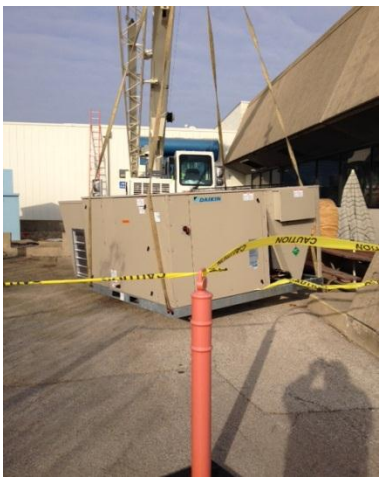
Linac Level-4 WBS completed (FY14-Q4).

WBS 1.1.5.2 LCW distribution

There are two main topics under this task: Dual Temp System Upgrade and CUB Chiller #3 backup pump.

Dual Temp System: During this quarter the installation of the rooftop unit was performed. Contractors worked on the Linac gallery during the month of November and December. Part of the installation work was to drain and isolate the original dual temp water pipes. The job proceeded by removing the fan coil units that distributed the cool/heat along the gallery. New duct lines were installed and appropriate sealed. Air handling vents were installed. In addition, the electrical upgrade to the power panel and the installation of new control unit was complete. In December 29, the AC rooftop unit was delivered and installed on the Linac gallery roof. Below is a picture of the unit staged awaiting to be installed.

Figure 5 Linac AC rooftop unit being prepared for install



The completion of this installation marks the completion of a Level-4 milestone: *Complete Installation of new dual temp system* and also completes another Level-4 WBS.

CUB Chiller #3 backup pump: During this quarter, the installation of the CUB chiller #3 backup pump was successfully installed. The concrete pad was poured in place early in the quarter. This step allowed the contractors to initiate their job. The pump was appropriate installed on the pad allowing the start of the custom fit of the plumbing installation. By middle November the system was ready to be tested. At the beginning of the test experts thought that the newly installed pump had bad bearings and would need to be pulled to repair. After further troubleshoot it was discovered that the pump had the wrong rotation. This was repaired a couple of weeks later. In addition, it was discovered that the pump was not sitting entirely flat on the pad. The concrete pad was poured not quite level and the pump had to be removed in order for the level repair to occur. After remounting the pump, the system was checked. This includes the automatic control that will monitor the flow and predict any failure of the primary pump which will employ the second pump and isolate the primary one. This was successful demonstrate.

The completion of this installation marks the completion of a Level-4 milestone: *Complete 55 LCW spare system* and also completes another Level-4 WBS.

WBS 1.1.5.3 Vacuum System

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.2 Booster

Part of the PIP effort for the Booster Accelerator is to address the increase proton beam flux that will be demanded by the Fermilab program in the upcoming years. The increased flux will be achieved by providing beam on more/all of the Booster cycles; certain equipment will increase from an average 7.5 Hz to 15Hz. Overheating of old components is a major concern; several Booster PIP tasks are to upgrade/refurbish equipment to run at 15 Hz.

The aging original equipment and infrastructure of the Booster are vulnerable due to obsolescence and increase wear due to the increase of flux. Some of the PIP effort is to replace these possible reliability problems.

WBS 1.2.1 RF

WBS 1.2.1.1 Anode Supply

Parts for the anode supplies have been received. Sub-assemblies are being constructed and tested. Final assembly will occur in FY15Q2 with testing to follow. During the 2015 shutdown, the anode supplies will be installed. Final documentation was completed for the task.

WBS 1.2.1.2 Bias Supply

The third retrofit bias supply was fully tested. A fourth retrofit bias supply was completed and a fifth retrofit was started. Two retrofit bias supplies are in operation.

WBS 1.2.1.3 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.1.4 Cavity Test Stand

The cavity test stand task will not be done since there will be no benefit to PIP.

WBS 1.2.1.5 Cavity and Tuners Refurbishment

The refurbishment of the thirteenth and fourteenth cavity tuner sets were completed this quarter. The time it takes to refurbish and test each set has averaged over the last three sets is a little more than eight weeks. No new problems/issues were encountered during this quarter.

The second cavity with taper damage was repaired and has been put back into operation.

WBS 1.2.1.6 New Tuners

Previously, a high power test stand for ferrite cores showed that one of four different core sets (two different permeabilities from two vendors) was acceptable. The acceptable core samples have been implemented into a tuner and been certified. The tuner was installed on a re-furbished cavity; the cavity has been operation since FY14Q4. A purchase order for enough ferrite cores to build twenty tuners was placed. The first part of the order arrived at the end of FY15Q1. Other components need to build new tuners have been ordered. Technical Division has started production of some sub-assemblies. The table 2 below is an example of the tests performed on the ferrites.

Table 1 Recent ferrite measured properties

Q measurement					
Bias Current (A)	0, before*	3000	5000	10000	0, after*
SG setting (dBm)	NA	7.0	7.0	7.0	NA
Max Cavity Voltage (V)	NA	9.00	10.40	11.40	NA
Resonant frequency (MHz)	36.109	41.911	42.348	42.777	38.324
f1	36.041	41.867	42.313	42.743	38.267
f2	36.180	41.961	42.381	42.807	38.385

WBS 1.2.1.7 New Cavities

Comparison of a model developed for the current Booster RF cavities and the temperature measurements taken as part of the refurbishment task continues. Further tests of cooling rates will be done to be compared with the simulation. A preliminary look into making small improvements to the cavity-tuner design is being done. Detailed temperature measurements were done during cavity and tuner set refurbishment certification (WBS 1.2.1.5); further measurements will be done during the next cavity tuner set certification.

We are continuing to investigate possible benefits of using a higher order harmonic cavity; in particular, for beam capture and transition crossing. We have been investigating a perpendicular biased cavity. Work previously done at SSC and TRUIMF was our starting point. Modelling and simulations progress has led to improvement over the old designs. Garnet samples have been procured and properties have been tested as suitability for a perpendicular biased cavity.

Although not new cavities, PIP has decided to reclaim two other cavities and rework them to be the 21st and 22nd Booster cavities (similar to the rework done for cavity 1013; WBS 1.2.1.8). In addition, PIP will implement three additional RF stations to bring the total number of Booster RF stations to 22. This requires electrical work, water cooling work, assembly of power equipment and cable pulling. The 20th RF station is to be completed during the 2015 shutdown and the remaining two RF stations to be completed in the following shutdown.

WBS 1.2.1.8 Cavity 1013

The cavity was put into operation in FY14Q4 and was operational during FY15Q1. There have been no problems with this reworked cavity. This task is considered complete.

WBS 1.2.2 Accelerator Physics

WBS 1.2.2.1 Simulations and Studies

The people assign to the task of organizing, performing and analyzing beam studies has been consistent for the last few quarters. The main work is being done by an accelerator scientist in the Proton Source Department. There are several physicists from the Accelerator Physics Center also involved. The control programs for adjusting the lattice and tunes have been combined. The resulting application can adjust either the lattice or tune without affecting the other. Testing of this application is on-going and has to not affect operations.

The Booster was operational most of this quarter. Work is on-going to smooth the orbit to an ideal orbit (see WBS 1.2.2.2), measure the optics and adjust optics throughout the ramp cycle.

WBS 1.2.2.2 Alignment and Aperture

Currently, no further magnets are scheduled to be moved. There are a few candidate magnets, but current simulation and beam studies (WBS 1.2.2.1) do not suggest that there will be noticeable improvement. The centers of the apertures have been designated as the ideal orbit (see WBS 1.2.2.1). We may return to this task in the future.

WBS 1.2.2.3 Booster Notcher

During the shutdown, the remainder of the short kicker magnets was installed. The remaining part of the power systems was also installed. After the shutdown, the entire Booster notcher system was commissioned. A spare kicker magnet has been constructed by Technical Division and tested. This task is considered complete.

WBS 1.2.2.4 Booster Cogging

A new electronics board has been used to mimic the existing system. The further capabilities of this prototype board are being implemented and tested. Code development associated with the new board is on-going. Beam tests of delivering cogged beam to a downstream accelerator were done and will continue in FY15Q2.

WBS 1.2.2.5 Booster Collimation

The collimation task is to control Booster beam loss after implementing the above notcher and cogging systems.

WBS 1.2.2.6 Radiation Shielding

Beam studies concerning the beam loss profile and measurements of beam loss radiation through penetrations have been done. Simulation studies involve the effectiveness of the passive shielding, active detectors and radioactive source terms for penetrations are nearly complete.

A Total Loss Monitor (TLM) system of eight long detectors has been installed; each detector covers three Booster periods. The assembly, testing and installation of the needed electronics continues. With the partial system of electronic components installed, beam loss tests and measurements have commenced.

WBS 1.2.3 Instrumentation

WBS 1.2.3.1 Beam Position Monitors

The specifications for the beam position monitor system are nearly complete and initial design work has started.

WBS 1.2.3.2 Dampers

Studies to verify damper design choices continue. Final requirements are being checked.

WBS 1.2.4 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.5 Utilities

WBS 1.2.5.1 Low Conductivity Water System

The task is done.

WBS 1.2.5.2 Power Distribution

The last power transformer has been manufactured. The transformer is identical to the two transformers previously purchased by PIP. Plans for installation during the shutdown were postponed when it was determined that the connection of this transformer is different than other replacements. During FY15Q1, engineers designed a solution and parts are being manufactured. The installation is now scheduled for the 2015 shutdown.

WBS 1.2.5.3 Vacuum System

The aged components will be replaced as opportunities present themselves with downtime of the Booster. Previously purchased vacuum equipment awaits opportunities for installation. During the shutdown, some vacuum work was done.

WBS 1.2.7 Solid State Upgrade

The task is done.

Booster Budget – Costs and Obligations Updates (FY15 Q1)

The FY15 first quarter had no significant budget changes. However, two tasks that were planned to be completed during the shutdown could not meet the schedule and have been extended into FY15. The extension of these jobs required funds to be carried over into FY15. The list includes: 1) Booster anodes supplies (both east and west), 2) Booster vacuum components (partly completed). Also as mentioned in the task section above and previous quarterly report, alignment of PIP to PIP II has impacted two high profile tasks. The first of these is PIP putting on hold labor and some material purchases for new cavities. A component of the alignment is to understand Booster RF cavities as required for PIP II and beyond. Another task affected by the alignment to P5/PIP II was the Linac high power klystron and gallery upgrade. The original plan to run Linac to 2025 and possibly beyond has been changed to 2023 and the start of PIP II. Funds allocated to these task are being allocated to those items suited for 2023 PIP II operations. PIP to PIP II alignment discussions are ongoing with plans to complete a document describing the necessary work to be released in FY15.

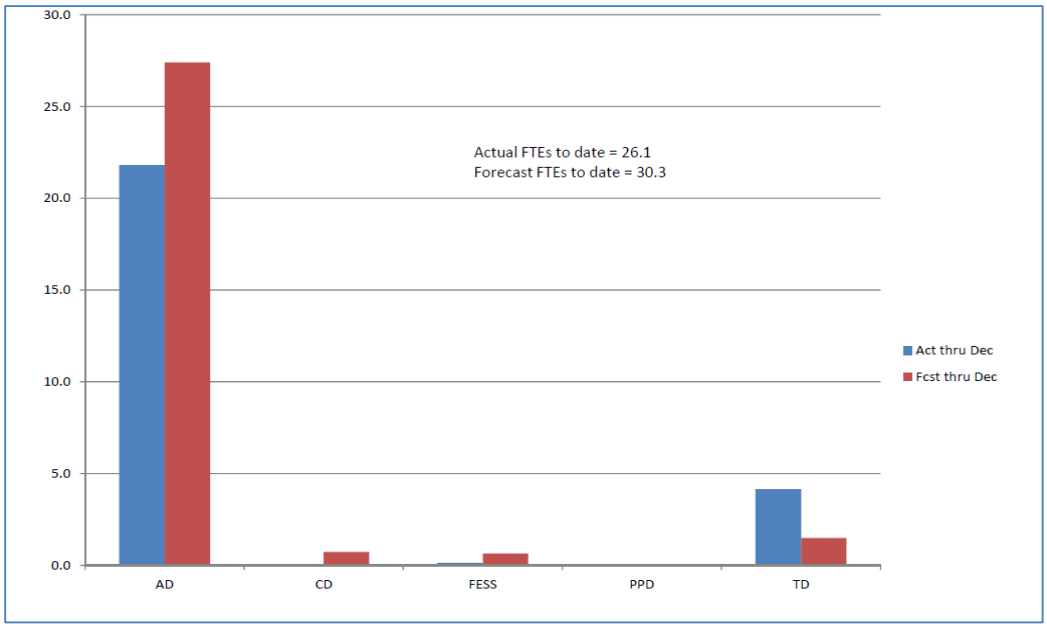
PIP budget and labor through December of FY15 are provided below. As already mentioned, the alignment of PIP to PIP II is underway. A budget profile has been provided to PIP and is shown in table 4 below. This schedule was the result of laboratory, DOE and PIP management discussions. The idea is to modify the necessary PIP tasks and resource schedule to align to PIP II.

Table 3 PIP FY15 final budget table summary

FY15 PIP OBL BUDGET K$ **	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	8,414.2	465.0	23.1	7,926.1
Labor	5,505.8	1,333.0		4,172.8
FY15 Sums	13,920.0	1,798.0	23.1	12,098.9

The labor for this past quarter as shown in figure 6 shows that the actual FTE count was lower than forecasted. There are two significant reasons for this difference. The first being the reduction in activities in for the Booster new cavities. The request to align to PIP II requires a review of the cavity specifications to ensure they are in line with PIP II Booster beam operations. The second reason is a delay in labor on some Booster items due to startup of the recycler after the shutdown. Labor for both the Booster BPMs and Damper was not available initially after the shutdown resulting in 1.2 less FTEs for those tasks.

Figure 6 PIP FY15 labor summary through December



As mentioned above, table 4 below provides a budget profile generated after recent budget exercises and reviews to have PIP scope align to PIP II. The net result is a reduction in the PIP budget of 12 million dollars. The reduction is due to the removal of production 200 MHz klystrons as mentioned in the task section above. Two additional items not originally included in PIP were added; Booster Sumps and Booster Feeder. The resource loaded schedule is being updated to reflect these changes and will be completed this FY. In addition, the effort to align the new Booster cavities is underway with a planning report to be completed this spring.

Table 4 PIP Budget after alignment to PIP II

		FY15 Plan	FY16 Plan	FY17 Plan	FY18 Plan	FY19 Plan	TOTAL
FY13 Plan	SWF	$5,974	$4,746				
	M&S	$6,026	$7,254				
	**SUM DOLLARS	$12,000	$11,500	$14,500	$11,000	$7,000	$90,000
	FTE	26.9	19.8	15	14	13	
Estimated reductions to profile based on PIP-II redirection (B)		($2,000)	($2,000)	($6,000)	($3,000)	$0	($13,000)
Estimated additions to profile to meet amended goals.			$0.50	$0.50			$1,000
PIP Present	Funds to completion	$10,000	$10,000	$9,000	$8,000	$7,000	$44,000

Members of both PIP and PIP II are meeting regularly to work out the details of the alignment activities – including cavities and beam physics. PIP continues to track the updated FY13 schedule and expects no significant delays in this FY. The rest of this year will be very busy with both 15 Hz related tasks and Linac modulator work. The plan is to reach 15 Hz capability before the summer shutdown.